

**COMPUTERIZED DESIGN SYNTHESIS (CDS),
A DATABASE-DRIVEN MULTIDISCIPLINARY DESIGN TOOL**

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INTRODUCTION

Few mechanical systems are subject to as severe and as varied an aeromechanical environment as the helicopter. For instance, in each revolution of the rotor blade airflow can vary from stall to compressibility effects in unsteady flow. Designing control of the vehicle by applying twist at the base of the long narrow blades is an exercise in aeroelastic abstruseness. In no other aircraft is structural efficiency more essential, with the structure subject to such a severe fatigue environment. While design problems for rotorcraft are fully as complex as for fixed wing aircraft, the available resources and response time may be even more strictly limited.

Timely, responsive, and accurate concept studies are essential in rotorcraft development. It is difficult for highly specialized technical design support to be flexible and responsive enough to contribute significant influence early in the design process, when fast turnaround on multiple concepts is required. Supporting specialized studies requires time and effort which parallels the design development. Often the key analysis results for a conceptual design are obtained only near design task completion, in time to verify the concept but sometimes too late to significantly influence key design decisions. Computerizing the design trade-off process is necessary in order to enhance the availability and flow of technical information. Teaming the technical specialist with the designer and a shared data base will produce timely responses to customer inquiries and improve the efficiency of the design process.

The Computerized Design Synthesis (CDS) system under development at McDonnell Douglas Helicopter Company (MDHC) is targeted to make revolutionary improvements in both response time and resource efficiency in the conceptual and preliminary design of rotorcraft systems. It makes the accumulated design data base and supporting technology analysis results readily available to designers and analysts of technology, systems, and production, and makes powerful design synthesis software available in a user friendly format.

COMPUTERIZED DESIGN SYNTHESIS (CDS)

A SYSTEM TO PUT ACCUMULATED DESIGN DATA BASE AND
SUPPORTING TECHNOLOGY ANALYSIS RESULTS READY
AT THE HANDS OF DESIGNER AND ANALYST,
AND TO MAKE DESIGN SYNTHESIS SOFTWARE AVAILABLE
IN A USER-FRIENDLY FORMAT.

LESSONS LEARNED

Industry experience in similarly ambitious computerized design systems provides some lessons learned. Potential problems include: data incompatibility, the profusion of specialized languages and codes evolving continuously, and the not uncommon experience that global programs, (with globe-sized promises) can consume vast resources and take years to develop. Furthermore, when they are finally developed, they are sometimes somewhat incomprehensible to the ordinary aircraft designer--having become the brain-child of a team of computer systems specialists.

LESSONS LEARNED

- GLOBAL PROGRAMS ARE COSTLY
- DATA COMPATIBILITY
- PROFUSION OF LANGUAGES
- GROWTH OF SPECIALTIES

OVERALL APPROACH

In the light of observed experience, a careful development path was defined to avoid some of the costs and difficulties, and to provide early return on investment. The basic system was established for the conceptual design problem, and is being expanded to support more and more preliminary design tasks. Scope is carefully limited. User friendliness is essential, with tutorial aids and built-in constraints against misapplication. The system is data base driven, with a library of menu-controlled vehicle and subsystem synthesis programs. Wherever practical, existing software was adapted, using the resources of other McDonnell Douglas Corporation components. A key policy has been to bring each new capability on-line as soon as it is viable, and to support operational usage during development. This provides early feedback to influence the system toward practical utility, and brings the earliest cost savings.

OVERALL APPROACH

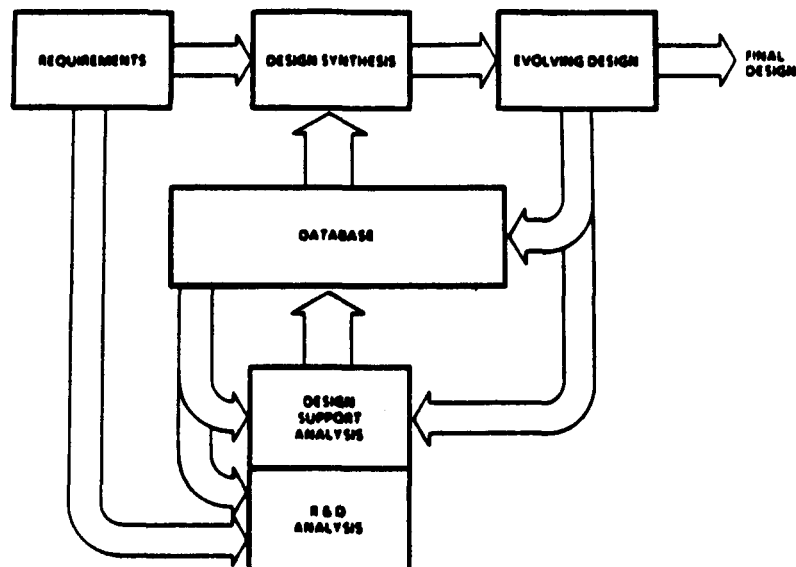
- TARGET: VEHICLE CONCEPTUAL DESIGN (RAPID VEHICLE SIZING),
CONCEPTUAL & PRELIMINARY DESIGN OF SUBSYSTEMS.
- LIMIT SCOPE, KEEP SYSTEM USER-FRIENDLY & TUTORIAL WITH
BUILT-IN CONSTRAINTS AGAINST MISAPPLICATION.
- DATA BASE-DRIVEN SYSTEM WITH LIBRARY OF MENU-CONTROLLED
VEHICLE & SUBSYSTEM SYNTHESIS PROGRAMS.
- ADAPT EXISTING SOFTWARE, PARTICIPATE IN MDC EXCHANGE
- SUPPORT OPERATIONAL USAGE DURING DEVELOPMENT

THE DATA BASE-DRIVEN SYSTEM

The CDS system was designed to be database-driven, as distinct from systems which are directly dependent on current customized applications of specialized analysis programs. Of course, such customized analyses are essential to the final refinement of preliminary and detail design. However, early and quick response efforts can use the data base for approximations, with parametric data developed from previous experience. The data base provides buffer storage between specialized design support analysis and the cyclic design process; making the analysis results available to the designer without the problems of language profusion and data incompatibility.

This is significantly different from many of the systems being developed for aerospace design support which are truly multidisciplinary, in that such analysis programs develop concurrent solutions from several separate disciplines. Those multi-disciplinary analysis programs remain specialized tools for the specialized analyst. Because familiarity with specialized theoretical mechanics is required, they are not suitable for direct use by the general aircraft designer--the one who is responsible for integrating the various specialized results.

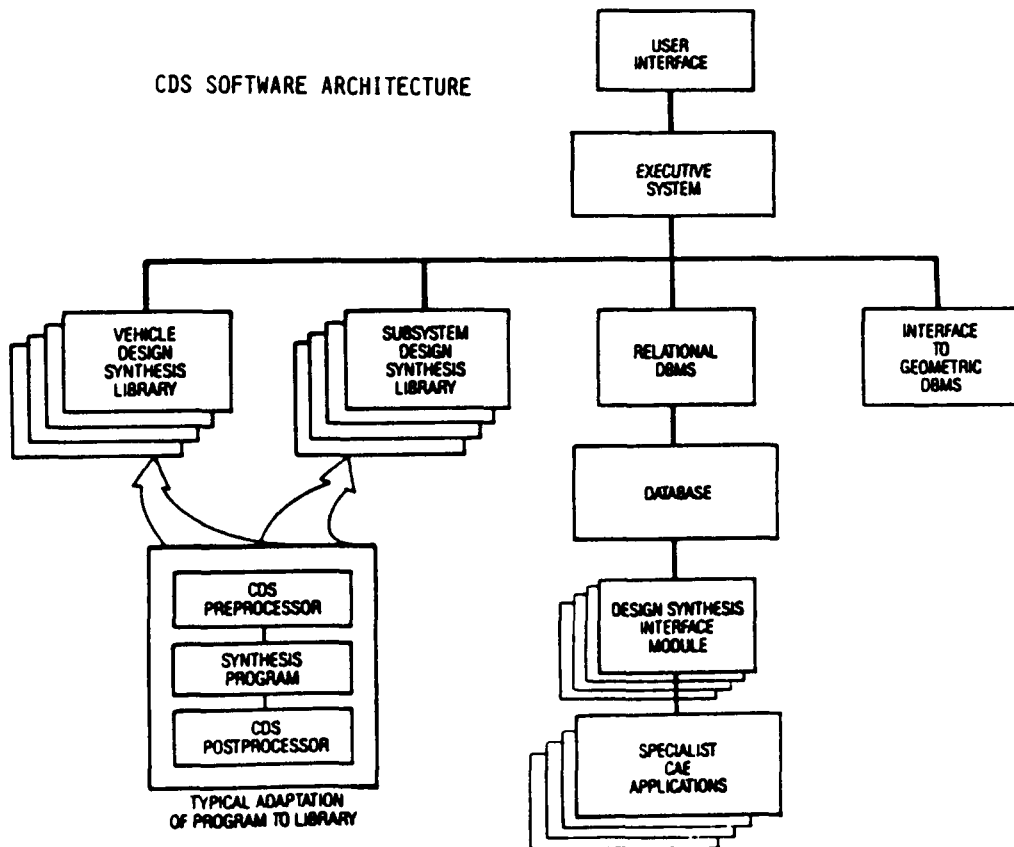
Data base-Driven Design Synthesis.



CDS SOFTWARE ARCHITECTURE

In the CDS system existing design synthesis software, for both vehicles and subsystems, is adapted by the addition of pre- and post-processors. These are managed through menu controls or commands, without the user being required to learn the intricacies of each program's jargon. This enables such programs as NASA's helicopter sizing and performance program "HESCOMP" (which contains over 14000 lines of code and requires over 4000 input parameters for operation) to be utilized in a highly simplified manner. The design synthesis library files include simulations of current vehicle designs. Through the menus of the executive system, these are easily used by designers and systems analysts to determine the effects on performance of variations in power, weight, fuel efficiency, and aerodynamics.

A commercially available relational database management system feeds data to the CDS executive system, which also interfaces with a geometric data base management system. The various specialized analyses are linked to the database through Design Synthesis Interface Modules (DSIM). These include programs from aerodynamics, acoustics, structures, thermodynamics, and other complex analytical disciplines; plus programs for evaluating process control, manufacturability, ballistic vulnerability, durability, etc. Each DSIM is, in effect, the data provider link for a highly technical supporting specialty. The DSIM also provides built-in constraints against misuse of the analytical data, informing the user if this difficulty should occur.



USER INTERFACE/MENU SUBROUTINES

The preprocessors which interface the programs in a design synthesis library assemble the program runstream, control parameters, and data deck according to the menu selections. The relevant choices are solicited and the user advised in the selections, and these are displayed in terms relating to the design mechanics (rather than relating to the program software). This process controls the program library and run options, component selections, missions, equipment, fuel, etc., for the model being exercised and the design requirements being served. It is also used to select output detail and format, plotting routines, and disposal of results, files, etc.

USER INTERFACE/MENU SUBROUTINES

OPTION CHOICES TO SET UP PRE- AND POST- PROCESSORS

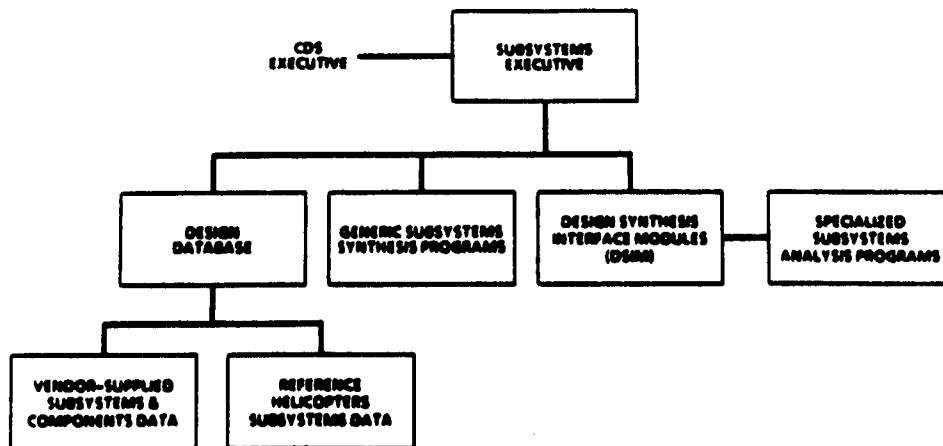
SOLICIT	}	PROGRAM LIBRARY OPTIONS
ADVISE		VEHICLE/COMPONENT SELECTIONS
DISPLAY		(ENGINES, CONFIGURATION, ETC.)
		MISSIONS, EQUIPMENT, FUEL
		SIZING AND/OR PERFORMANCE OPTIONS
		OUTPUT DETAIL
		PLOTTING ROUTINES
		BATCH/MULTIPLE RUN CONTROL
		FILE STORAGE AND CONTROL

SUBSYSTEMS DESIGN SYNTHESIS

All specialized analyses are treated autonomously by establishing an interface module (DSIM). This includes software providing graphic anthropometric modeling for cockpit layout and programs for design of drivetrains, engines, environmental control systems, and mission equipment packages. These provide the more advanced connection, to the analyses customized for the design task in progress.

The more ready-at-hand support is from reference data and generic simulation routines directly available through the subsystems executive. Such reference data include vendor-supplied information and published data collected in the data base.

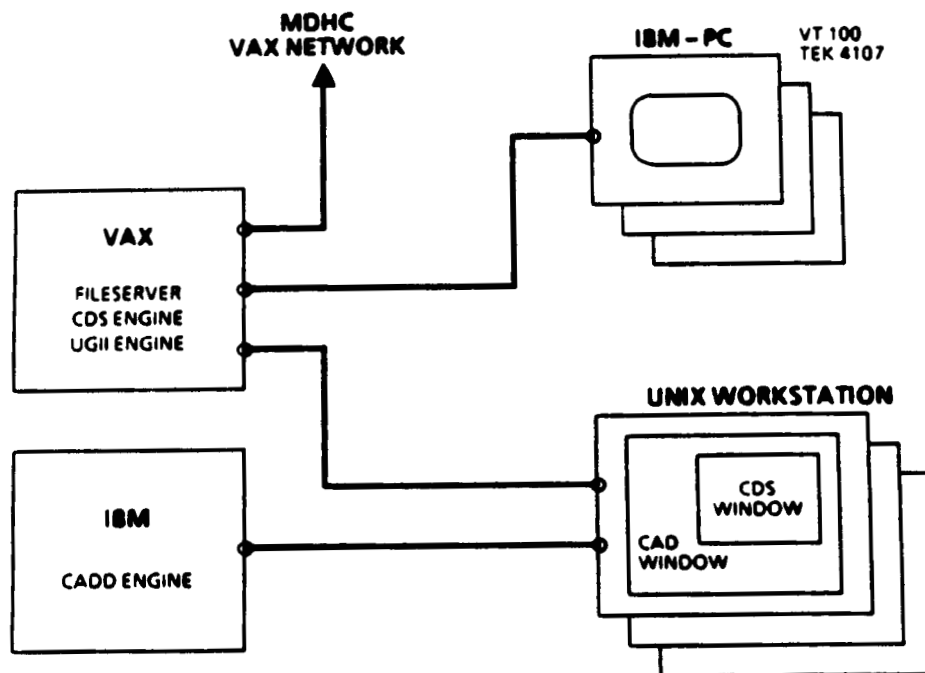
Computerized Design Subsystems Synthesis.



HARDWARE ARCHITECTURE

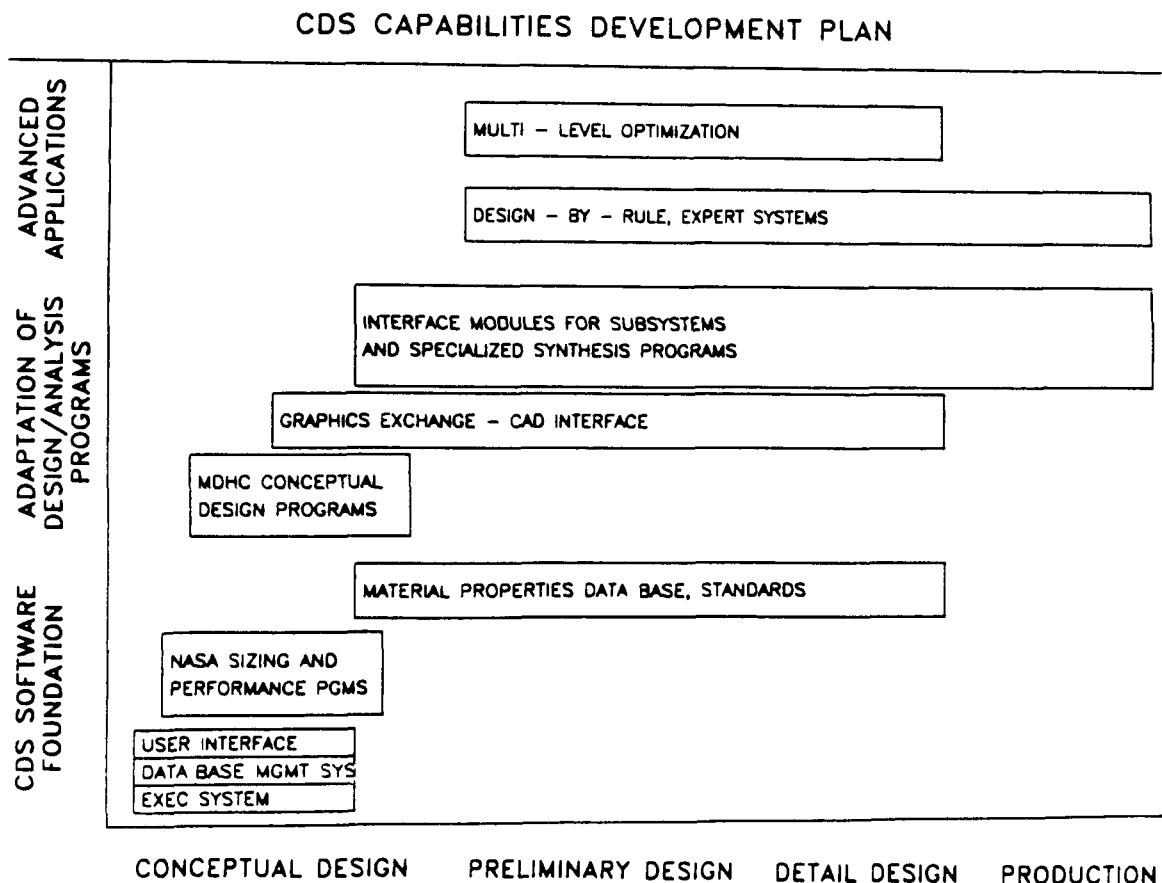
The CDS system is initially implemented on the VAX/VMS environment where the bulk of the specialized CAE application programs are installed. The CDS system will later be ported to a distributed computing environment that includes UNIX based workstations, file servers and compute servers all networked together.

CDS Hardware Architecture.



CAPABILITIES DEVELOPMENT PLAN

The adaptation of powerful conceptual design synthesis software such as NASA's HESCOMP helicopter sizing and performance program to the CDS executive system brings an immediate payoff in productivity, which in turn can fund further development of the system. As each new capability is developed and proven, it is added on-line to the CDS repertoire. The executive system, data base management system, and user interfaces have been developed for the conceptual design task. They are being expanded to incorporate the analytical support for the much more complex preliminary design task. This figure shows the capabilities being added, by category, with the abscissa representing both calendar time and design application category. Currently the basic system is in place for conceptual design, and improved in-house modules are being added which allow considerable choice in the level of detail to be used. The data base is being expanded to provide structural material data required for preliminary design, and Design Synthesis Interface Modules (DSIM) are being developed for drivetrain and structural component design synthesis. A graphics exchange interface will link graphic data from Unigraphics II and allow such exercises as putting the anthropometric model of program MACMAN in the cockpits being designed from the results of conceptual design trades.

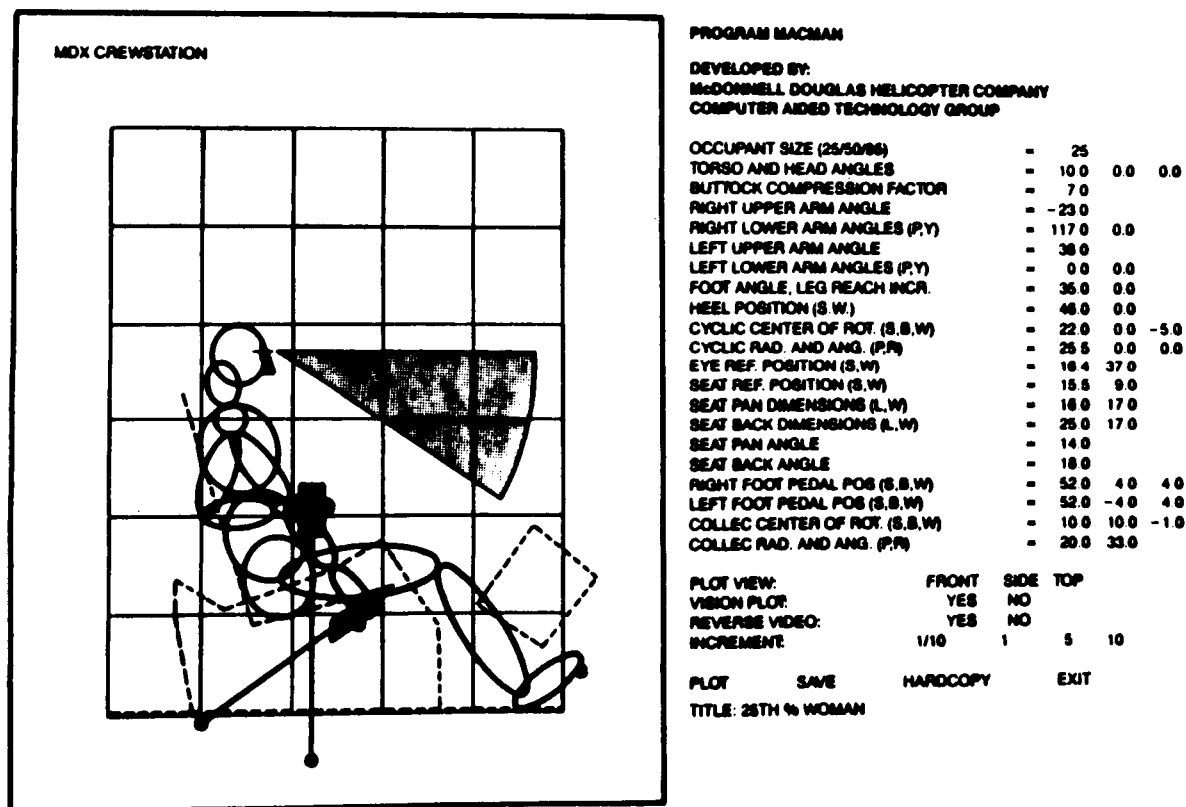


MACMAN: ANTHROPOMETRIC MODELING FOR CREW STATION DESIGN

Program MACMAN generates and manipulates a graphic depiction of a three-dimensional human body composed of linked ellipsoidal components. The default model is dimensioned to fit the 50th percentile Army man in overall size, with body components of standard proportion. Alternatively, size can be selected representing 25th or 5th percentile women, and 50th or 95th percentile men, based on NASA civilian data. Disproportionate figures can also be modeled. For example, a 50th percentile torso can be combined with 45th percentile legs and 52nd percentile arms. The program was used supporting conceptual design for the MDX light helicopter project, determining the following:

1. Seat position: height and limits of fore and aft adjustment.
2. Rudder pedal position and adjustments.
3. Seat back pan size and orientation.
4. Control locations for cyclic and collective.

The figure's limbs are animated. The entire graphical analysis is interactive, with 49 variables at the menu command of the operator.



MACMAN Workstation Display, Side View.

STRUCTURAL COMPONENT DESIGN SYNTHESIS

Despite the fact that the technology of formal structural optimization has reached a state of practical applicability, the majority of structural component design tasks are still accomplished by the traditional draw-then-analyse procedure. If the component is not too complex, the designer can use handy stress formulae so that his first attempt is reasonable and then refined analysis can be used to tune the design. However, for most composite laminates the structural design task becomes complex, simply because of the increased number of design options opened up by the material and layup combinations. For such components there are also an increased number of failure modes to consider. A valuable step forward can be attained by putting user friendly analysis tools in the designers hands, and using the computer, with a small knowledge base associated with design practice, to illuminate design options and results. By providing information on selected bounds in design space, the designer can make optimal choices on a traditional heuristic basis. The software so developed forms a base for future expansion into applications of formal optimization.

A variety of stress analysis software is being inverted to provide solutions to the design problem instead of the stress analysis problem. (In the design problem stress is an allowable rather than a result.) Of course, when the problem is nonlinear, the relevant equations cannot be inverted directly, but a programmed series of forward runs can be used in mapping available design space.

COMPOSITE PANEL DESIGN TRADES

SANDWICH PANEL

BUCKLING, SHEAR, COMPRESSIVE FAILURE LIMITS PER:

- * FACING LAYUP, THICKNESS
- * CORE MATERIAL, THICKNESS
- * FACING HYBRID MATERIAL LAMINA

STIFFENED PANEL

BUCKLING, LOCAL CRIPPLING, JOINT FAILURE LIMITS PER:

- * PANEL LAYUP, THICKNESS
- * STIFFENER TYPE, SIZE, SPACING
- * HYBRID MATERIAL LAMINA